PATENT APPLICATION
ATTORNEY DOCKET NO. 06558.011001

APPLICATION

FOR

UNITED STATES LETTERS PATENT

TITLE: **SEABED OIL STORAGE AND TANKER OFFTAKE SYSTEM**

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22511
PATENT TRADEMARK OFFICE

"EXPRESS MAIL" Mailing Label Number: EL656797009US
Date of Deposit: 3-27-2001

SEABED OIL STORAGE AND TANKER OFFTAKE SYSTEM

Background of Invention

Field of the Invention

[0001] The invention relates generally to offshore oil production and, more particularly, to offshore oil storage that can be used for deepwater applications.

Background Art

[0002] A major factor in determining whether or not to exploit an offshore oil and gas field is the feasibility of handling and transporting the hydrocarbons to market once they are produced. Generally, hydrocarbons produced offshore must be transported to land-based facilities for subsequent processing and distribution. Temporary storage may be provided at the offshore production site for holding limited quantities of hydrocarbons produced and awaiting transport to shore. In some cases, equipment is also provided at the offshore production site for separating and/or treating the produced hydrocarbons prior to storing and transporting them to shore.

[0003] In the case of an offshore production facility located relatively close to shore, hydrocarbons produced may be feasibly transported to shore through a pipeline system extending from the offshore site (*e.g.*, offshore platform or subsea wells) to the shore along the ocean floor or seabed. This type of pipeline system is typically preferred, when feasible, because it permits the constant flow of hydrocarbons to shore regardless of the weather or other adverse conditions. However, in some parts of the world, the use of a seabed pipeline system for transporting hydrocarbons to shore may result in expensive pipeline tariffs.

[0004] For offshore facilities located a great distance from shore, construction of a pipeline to shore is typically not practicable. In these cases, floating vessels, known as tankers, are used to transport hydrocarbons to shore. Tankers are specially designed vessels which have liquid hydrocarbon storage (or holding) facilities, typically, in the hull of the vessel. In the case of crude oil production, water, vapor, and other impurities are typically removed from the oil prior to offloading the oil onto tankers for transport. In some cases, tankers include additional equipment for separating and treating crude oil prior to storage and transport.

[0005] Because tankers float on the water surface, their operations are largely dependent upon surface conditions, such as wind, wave, and current conditions. Thus, tankers are typically not operated during severe or unfavorable conditions. Additionally, operation of a particular tanker may be interrupted periodically for maintenance and repairs. Due to the large expense associated with maintaining tankers, tankers may also be shared among several offshore sites. As a result, long delay periods may occur between tanker availability for a particular site. Therefore, it is desirable to have storage facilities available at the offshore site to avoid the need to "shut-in" (or halt) production due to tanker unavailability. Additionally, offshore storage may be desired to allow for continuous production operations, independent of tanker hook-up and disconnect operations, as discussed below.

[0006] Examples of existing offshore production and storage systems used for deepwater applications are illustrated in Figure 1 and in Figures 2A-2D. Figure 1 shows one example of a production platform **2** used in a deepwater application. This platform **2** includes processing and storage equipment **4** for separating and treating crude oil collected from subsea wells **6** and storing a limited quantity of

the processed oil when transport is not available. Because the surface area and weight carrying capacity of the production platform **2** is extremely limited, storage facilities provided on a platform **2** are limited in size and, thus, inadequate for handling large quantities of hydrocarbons which may be produced during periods of shuttle tanker or other hydrocarbon transport unavailability.

[0007] Figure 2A shows a floating production, storage, and offloading (FPSO) system **10** which comprises a tanker **11** specially equipped to function as an offshore production facility. The FPSO tanker **11** is permanently moored at the offshore site and connects to the subsea wells or subsea production gathering system **14** through one or more flowlines **18** connected to the production inlet **16** of the FPSO tanker **11**. During production operations, produced hydrocarbons are received, directly or indirectly, from the subsea wells **14**. Once on the FPSO tanker **11**, hydrocarbons are processed and temporarily stored. Hydrocarbons stored on the FPSO tanker **11** are periodically transferred onto a shuttle tanker **12** temporarily positioned in the vicinity of the FPSO tanker **11** during the transfer. Because FPSO systems **10** comprise surface vessels, they are susceptible to severe weather conditions, during which production must be interrupted and the flowlines **16** leading to the FPSO tanker **11** disconnected. Furthermore, positioning of the shuttle tanker **12** close to the FPSO tanker **11** for hydrocarbon transfer is typically limited to relatively calm weather conditions. As a result, the storage space on the FPSO system **10** may become full and production may have to be halted until a shuttle tanker **12** for offloading is provided.

[0008] Figure 2B shows one example of a floating storage and offloading (FSO) system **20**, which is a pure form of ship-based storage without production facilities on board. Using this type of storage system, produced hydrocarbons from a production platform **22** are transferred to an FSO vessel **26** via a flowline (not

shown) extending from the production platform **22** to the FSO system **20**. Hydrocarbons transferred to the FSO vessel **26** are stored, typically in the hull of the FSO vessel **26**. From the FSO vessel **26**, produced hydrocarbons are periodically offloaded onto a shuttle tanker **24** for transport to shore. As in the case of the FPSO system **10** discussed above with reference to Figure 2A, production operations which depend upon an FSO system **20** for storage may be susceptible to production interruptions due to severe weather conditions. Also, during periods when a shuttle tanker **24** is not available for offloading the storage facility on the FSO vessel **26**, it may become full requiring interruption of production until a shuttle tanker **24** is available.

[0009] Figure 2C is an illustration of a direct shuttle loading (DSL) system **30**. In a DSL system **30** hydrocarbons produced from subsea wells **33** are collected at an offshore production gathering system, in this case a production platform **32**, and directly offloaded onto a shuttle tanker **34, 38** when available, through a flowline **36**. For the DSL system shown in Figure 2C, hydrocarbons are loaded onto one shuttle tanker **34** for transport to shore while another shuttle tanker **38** waits nearby for subsequent offloading after the first tanker **34** is full and en route to shore. Like other tanker-based storage systems described above, production operations which use DSL systems **30** are susceptible to interruptions in production due to severe weather conditions and periods of shuttle tanker unavailability. Additionally, the use of a DSL system **30** may require operation of a larger shuttle tanker fleet because the presence of at least one shuttle tanker **34, 38** is required at substantially all times in order for production operations to continue. Further, in cases where no temporary storage is provided at the production site, hydrocarbon production will be interrupted every time a shuttle tanker **34, 38** is connected or disconnected for offloading and transport.

[0010] Production platforms have also been developed to integrate oil storage into the hull **44** of a platform, such as a SPAR platform **40** as shown in Figure 2D. However, in cases involving significant production volumes, this storage is not adequate during periods of tanker unavailability. Thus, frequent tanker hook-ups to the platform **40** will still be required. In such cases, even a system comprising a platform **40** with integral storage is still too dependent upon the presence of a shuttle tanker **42**.

[0011] Other offshore storage systems for deepwater applications may also include smaller thick-walled tanks designed to be sunk to the seabed and internally controlled from the surface. Because the interiors of these tanks are completely isolated from the surrounding seawater environment, these tanks require very thick walls to withstand the hydrostatic pressure difference between the subsea environment and the platform environment. As a result, these systems are expensive and limited in capacity. These systems also require additional equipment such as pumps, controls, and other instrumentation, for monitoring and controlling the internal tank environment and moving fluids in and out of the tanks.

[0012] Other offshore storage systems exist for use in shallow water applications; however, for the most part, these systems are not applicable for use in deepwater applications.

[0013] In view of the above, a need exists for a cost-effective storage system that can be used for deepwater production operations which provides adequate facilities for storing hydrocarbons and acts as a buffer between tanker loadings. Having such a storage system may avoid the need to halt production until tanker availability and may help to increase the profitability of an offshore production

site or to increase the feasibility of developing production sites in remote offshore locations.

Summary of the Invention

[0014] The invention relates to a system for storing liquid hydrocarbons, such as oil, in a tank located on a seabed and offloading the stored hydrocarbons from the tank onto transport vessels when they are available for transporting hydrocarbons to shore. Embodiments of the invention may be used in conjunction with an offshore production facility, such as an offshore platform, or a subsea production and processing system. Embodiments of the invention may also, advantageously, provide a more feasible large capacity hydrocarbon storage option, particularly for deepwater hydrocarbon production.

[0015] In one embodiment the system includes a storage tank attachable to the seabed and adapted to store hydrocarbons therein. The system also includes at least one fluid channel having a first end positioned inside the tank proximal the bottom of the tank, and a second end in fluid communication with seawater outside of the tank. The system also includes at least one offload line having a first end coupled to and in fluid communication with the tank proximal a top of the tank and a second end adapted to be fluid coupled to a tanker and accessible from a water surface. The system further includes at least one hawser having a first end operatively coupled to the tank and a second end adapted to be accessible from the water surface and attachable to a tanker to anchor the tanker during tanker offtake operations.

[0016] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

Brief Description of the Drawings

[0017] Figure 1 shows a prior art offshore production platform with processing and storage equipment on the platform.

[0018] Figure 2A is an illustration of a prior art Floating Production, Storage, and Offloading systems.

[0019] Figure 2B is an illustration of a prior art Floating Storage and Offloading system.

[0020] Figure 2C is an illustration of a prior art Direct Shuttle Loading system.

[0021] Figure 2D shows a prior art SPAR platform with an integral storage facility.

[0022] Figure 3 shows an embodiment of a seabed oil storage and offtake system in accordance with the present invention.

[0023] Figure 4 shows an embodiment of a seabed oil storage and offtake system configured to supply production to a shuttle tanker.

[0024] Figure 5 is an illustration of an embodiment of a seabed oil storage and offtake system in oil fill mode.

[0025] Figure 6 is an illustration of an embodiment of a seabed oil storage and offtake system in oil offtake mode.

[0026] Figure 7 shows an embodiment of a seabed oil storage and offtake system used in connection with a subsea processing system.

[0027] Figure 8 shows an embodiment of a seabed oil storage and offtake system used in connection with a subsea processing system.

[0028] Figure 9 shows an embodiment of a seabed oil storage and offtake system used in connection with a tension leg platform.

[0029] Figure 10 shows an embodiment of a seabed oil storage system used in connection with a SPAR platform.

Detailed Description

[0030] Referring to the drawings wherein like reference characters are used for like parts throughout the several views, Figure 3 shows one embodiment of a seabed hydrocarbon storage and offtake system in accordance with the present invention. The storage and offtake system comprises a storage tank **100** adapted for placement on and, preferably, attachment to the seabed **114**. The tank **100** comprises a top **100a**, a bottom **100b**, and one or more side walls **100c**. At the base of the tank **100**, there is an amount of fixed ballast, such as sand, concrete or other dense material, to provide submerged weight to overcome the buoyancy force of the hydrocarbon when the tank **100** is filled to its maximum storage capacity.

[0031] The tank may comprise any configuration as determined by one skilled in the art, including cylindrical-shaped, box-shaped, or the like. Those skilled in the art will appreciate that the configuration of the tank is a matter of convenience for the system designer. For example, in a particular embodiment, the tank may comprise a box-shaped configuration and a web-framed steel structure so that it may be constructed using standard ship building techniques, launched from conventional shipways, and have stable floatation for open-water tow.

[0032] The storage and offtake system further comprises at least one fluid channel **127,** such as a standpipe more distinctly illustrated in Figures 5 and 6. As shown in the embodiment in Figures 5 and 6, the fluid channel **127** has a first end **124a** positioned inside of the tank **100** proximal the bottom **100b** of the tank **100** and a second end **124b** in fluid communication with the seawater environment **125**

outside of the tank **100**. Preferably the second end **124b** is positioned away from the seabed (**114** in Figure 3).

[0033] Referring once again to Figure 3, the storage and offtake system further comprises at least one offload line **103**. The offload line **103** comprises a first end coupled to the tank **100** and in fluid communication with the interior of the tank **100** proximal the top **100a** of the tank **100**. A second end of the offload line **103** is adapted to couple in fluid communication to a transport vessel (illustrated in Figure 4) and to be accessible, in a manner which will be further explained, from the water surface **116**.

[0034] The storage and offtake system further comprises a vessel mooring system which comprises at least one hawser **110**. As shown in Figure 3, the hawser **110** comprises a first end operatively coupled to the tank **100** and a second end adapted to be accessible from the water surface **116**. The second end is also adapted to attach to the transport vessel to anchor the transport vessel during offloading operations, as illustrated in Figure 4.

[0035] Referring once again to Figure 3, suction or conventional piles **102** may be used to attach the tank **100** to the seabed **114** to provide lateral resistance for the tank **100** to sliding due to the slope of the seabed or other lateral forces that may be applied to the storage tank **100** during operation. Additionally, the piles **102** may also act as a restraint for the storage tank **100** which provides mooring for the tanker during offloading operations (illustrated in Figure 4).

[0036] It should be understood that the storage tank **100** may comprise any material suitable for use as a tank such as steel or a composite material such as glass or carbon fiber reinforced plastic. The inside and outside of the tank **100** may also be coated with cement or any other coating material known in the art for protecting structures formed from a metal such as steel against deterioration due to

operation in a saltwater environment. Preferably, the storage tank **100** is a gravity based, pressure balanced structure, as will be described in more detail.

[0037] The lower portion of the offload line **103** in this embodiment comprises a substantially rigid member, such as a marine riser **104**. As shown in Figures 3 and 4, the riser **104** in this embodiment comprises a self-standing, top-tensioned riser; wherein one end of the riser **104** connects to the top of the storage tank **100** and the other end of the riser **104** connects to a subsurface buoyant device (for example, subsurface buoy **106**) to maintain the riser **104** in tension in a substantially upright position when the system is submerged in water. To facilitate the interface between the lower end of the riser **104** and the top of the tank **100a**, a Lower Marine Riser Package (LMRP) may be used, such as one available from ABB Vetco-Gray, Houston, Texas, or a similar device. Preferably, the riser **104** also functions as part of the transport vessel mooring system (further described below). In such case, the riser **104** should be designed to withstand the additional forces expected to be imposed on it by mooring a tanker (illustrated in Figure 4) to the tank **100** via the riser **104**. Those skilled in the art will appreciate that the riser **104**, or the like, may comprise any material suitable for the particular application, such as steel or a composite material. Additionally, the external surface of the riser **104** exposed to the seawater environment may be coated with a suitable protective material.

[0038] As previously described and shown in Figure 3, a subsurface buoy **106**, or other buoyant device, may be attached to the upper end of the riser **104** to maintain the riser **104** in an upright position and in tension. For example, the subsurface buoy **106** illustrated in Figure 3 may comprise one or more chambers filled with fluid substantially lighter than seawater, such as air or oil, and a center passage

there through for the top of the riser **104** to interface with an end of the upper portion of the offload line **103**.

[0039] Also as shown in Figure 3, the subsurface buoy **106** and the upper end of the riser **104** are located a selected distance below the water surface **116**. This distance, more preferably, is such that the effects of surface environmental loads, such as the wind, waves, and current, on the subsurface buoy **106** and riser **104** will be feasibly minimized. A desirable depth for a particular embodiment is site specific and may be determined by one skilled in the art based on factors such as the structural integrity of a selected riser **104** (e.g., rigidity, length, and tension) and worst case environmental operating conditions, such as a 1-year, 10-year, or 100-year worst storm criteria for the particular sea state. For example, based on the structural integrity of a particular riser and particular storm criteria, a subsurface buoyant device may be located at a depth below the water surface such that the effects of waves and surface currents on the buoyant device is less than 10%, or more preferably less than 2%, of the effect if the buoyant device was located at the water surface **116**. In some cases this depth may be at least 50 feet below the water surface **116**. In other cases this depth may be at least 200 feet below the water surface **116**. However, criteria used to determine the desired depth of the subsurface buoyant device and the selected depth are matters of convenience for a system designer, and not intended as a limitation on the invention. Further, those skilled in the art will appreciate that in the case of the riser **104** used as part of the mooring system (further described below), the tension needed on the riser can be determined based on factors such as the size of the shuttle tanker to be moored, the water depth in which the system is installed, environmental conditions (such as wind, waves, and current) at the particular site, and the worst storm conditions for which the system is designed to function.

[0040] The upper portion of the offload line **103** may comprise a flexible member, such as a hose or series of rigid segments (*e.g.*, subpipe sections) coupled by flex joints. In the embodiment shown in Figures 3 and 4, the flexible member comprises a hose **108**. The hose **108** provides a flexible fluid channel which extends from the top of the riser **104** to the water surface **116**. The hose **108** is in fluid communication with the riser **104** through the subsurface buoy **106** to transfer hydrocarbons (oil) from the tank **100** to a transport vessel such as a shuttle tanker (shown as **113** in Figure 4) or the like. In this embodiment, the lower end of the hose **108** is attached to the top of the riser **104** at the subsurface buoy **106**, and the upper end of the hose **108** is attached to a surface buoy **112** so that the hose **108** can be easily accessed from the water surface **116** for offloading (or offtake) operations. Those skilled in the art will appreciate that the flexible upper portion of the offload line **103** may comprise any material suitable for a particular application, such as rubber, metal, composite material, or a combination thereof.

[0041] As shown in Figures 3 and 4, in one embodiment, the hawser **110** operatively couples to the tank **100** through the riser **104**. One end of the hawser **110** is connected to the subsurface buoy **106** at the upper end of the riser **104**. The other end of the hawser **110** is connected to the surface buoy **112**. As a result, the hawser **110** can be used to anchor a transport vessel, such as a shuttle tanker (**113** in Figure 4) or the like, to the tank **100** during offloading operations, or during servicing of the system. In this embodiment, the hawser **110** is shorter in length than the hose **108**, which ensures that the hawser **110**, and not the hose **108**, provides the anchoring connection between the riser **104** and any vessel connected to the hawser **110** at the water surface **116**. Those skilled in the art will appreciate that in other embodiments, the hawser **110** may be operatively coupled to the tank **100** in a manner different than the manner shown in Figures 3 and 4, without departing from the spirit of the invention. Those skilled in the art will also

appreciate that hawsers for mooring transport vessels and the like are well known in the art and that any type of hawser considered suitable for a particular application by a system designer may be used for the system without departing from the spirit of the invention.

[0042] As previously explained with respect to Figures 3 and 4, one or more buoyant devices, such as surface buoy **112**, may be attached to the upper end of the hose **108** and the upper end of the hawser **110** to maintain the surface ends thereof so that they are easily accessible at the water surface **116**. In some embodiments, the storage and offtake system may also include a coupling, such as a flex joint **118** and/or swivel joint **120**, disposed between the riser **104** and the hose **108** and/or the riser **104** and the hawser **110** to enable the hose **108** and the hawser **110** to rotate freely with respect to the riser **104**. In the embodiment shown in Figure 3, the flex joint **118** is positioned between the riser **104** and the subsurface buoy **106**, and a swivel joint **120** is positioned between the top of the riser **104** and the ends of the hose **108** and hawser **110** proximal the subsurface buoy **106**. Additionally, the system may include any connection device known in the art at the accessible end of each of the hose **108** and the hawser **110** for releasably connecting the hose **108** and the hawser **110** to a tanker **113** or other transport vessel during offloading operations.

[0043] Now referring to Figures 5 and 6, as previously discussed, the storage tank **100** of the system is substantially pressure balanced. This pressure balance can be achieved by providing that the inside of the tank **100** is in fluid communication with the seawater environment outside of the tank **100** at substantially the same depth. Those skilled in the art will appreciate that in the case of a pressure balanced tank **100**, the transportation and installation loads, rather than differential pressure across the tank **100** during operation will primarily affect the structural

design of the tank **100**. This allows for pressure balanced tanks to have substantially reduced wall thickness in comparison to enclosed storage systems on the seabed which are subject to hydrostatic pressure differences across the walls of the tank. This also allows for feasible tanks with larger storage capacities, such as up to 2 million barrels of oil, for deepwater service, such as in depths up to 10,000 feet of water, or more. In a particular embodiment, for example, the tank may have dimensions of about 200 feet long, about 200 feet wide, and about 150 feet tall and may have a capacity around 750,000 barrels. Thus, embodiments of the invention may provide a lower cost option and/or increased storage capacity than other storage systems.

[0044] Examples of a pressure balanced tank during normal operations in accordance with the above description are shown in Figures 5 and 6. Figure 5 is an illustration of a storage tank **100** during a "filling" operation. Figure 6 is an illustration of a storage tank **100** during an "offtake" operation. In the examples shown, the pressure balance is achieved through the use of a fluid channel **127**, which extends from a lower location inside of the storage tank **100** through an upper section of the tank **100** and into the surrounding seawater environment **125**. The fluid channel **127** allows the interior of the storage tank **100** to be in fluid communication with the seawater environment **125**. Hydrocarbons **121** entering the tank **100** will float to the top **100a** of the tank **100** and become trapped in the riser **104** and the upper portion of the tank **100**, thereby displacing water **123** in the tank to the bottom **100b** of the tank **100**.

[0045] Those skilled in the art will appreciate that the tank **100** may additionally include instrumentation to ensure that the maximum and minimum oil **121** and water **123** levels for a selected tank design are not exceeded. Those skilled in the art will also appreciate that the fluid channel **127** may comprise any configuration

and may communicate with the seawater environment outside of the tank **100** at any location, such as through a side wall of the tank **100**, as determined by the system designer without departing from the spirit of the invention. However, in a particular embodiment the fluid channel **127**, preferably, is in fluid communication with the surrounding seawater environment **125** at a location away from the seabed (**114** in Figure 3 and 4), as further discussed below.

[0046] As shown in Figure 5 (and Figure 6), the fluid channel **127** may extend through the top of the tank **100** to elevate the point of water discharge (and intake) at the external end **124** of the fluid channel **127**, away from the seabed (at **114** in Figures 3 and 4). Locating the external end **124** of the fluid channel **127** away from the seabed (**114** in Figures 3 and 4), advantageously, improves the dispersion of seawater exiting the tank and prevents scouring around the base of the storage tank **100**. A storage tank **100** with a fluid channel **127** as shown in Figures 5 and 6 is functionally the same as an opened bottom tank with respect to pressure-balancing the tank. However, a storage tank **100** with a fluid channel **127** for seawater intake and discharge is more effective because it eliminates problems associated with water dispersion and scouring around the base of the tank **100**. Additionally, a storage tank **100** having a fluid channel **127** arrangement as shown may also allow for improved monitoring and control of seawater flow in and out of the storage tank **100** in comparison to open bottom tanks. For example, the system may additionally include instrumentation in or proximal to an end of the fluid channel **127** for monitoring and controlling fluid flow through the fluid channel **127** as determined by the system designer. For instance, a device measuring the resistivity of fluids or residue oil content in the water leaving the fluid channel **127** may be included in the system.

[0047] Referring to Figure 5, during production operations, as hydrocarbons enter the storage tank **100** through the inlet **122**, the hydrocarbon/water interface **129** is pushed downward displacing seawater **123** out of the fluid channel **127** and into the surrounding seawater environment **125**. It should be understood that in a preferred embodiment, this hydrocarbon/water interface **129** is naturally formed by pumping hydrocarbons (oil) **121** directly on water **123** in the tank and allowing the hydrocarbons **121** to naturally rise to the top of the tank **100** displacing water **123** to the lower section of the tank **100**. However, in other embodiments this interface **129** may be mechanically maintained using a flexible or permeable membrane member in the tank which is displaced in the tank as hydrocarbons **121** flow in or out of the tank **100**, without departing from the spirit of the invention.

[0048] Referring now to Figure 6, during offtake operations, hydrocarbons **121** in the tank **100** may be offloaded onto a transport vessel, such as a shuttle tanker (**113** in Figure 4) or the like for transport to shore. For example, once the transport vessel is moored using the hawser **110** (in Figure 4), and the hose **108** (in Figure 4) is connected to the vessel, a surface valve or other remotely located valve, such as at **128**, is opened and the hydrostatic pressure imbalance due to the gravity difference between the hydrocarbon and seawater columns provides the motive force required to force the hydrocarbons **121** up the riser **104** and hose **108** (in Figure 4) to the transport vessel at the surface **116**. Thus, advantageously, no pump is required to lift the hydrocarbons **121** from the storage tank **100** to the shuttle tanker (**113** in Figure 4) during the offtake operation. The energy available to transport hydrocarbons **121** up the offload line **103** (in Figure 4) is substantially equal to the hydrostatic pressure difference between the hydrocarbons **121** and seawater **123** columns. For example, for a 30° API oil stored in a tank at a 6,000-foot water depth, the differential pressure between the fluid columns will be about

325 psi, which is more than sufficient to move the hydrocarbons **121** up the offload line **103** (in Figure 4) and into a tanker **113**.

[0049] Now referring again to Figure 3, one skilled in the art will appreciate that to install a seabed storage tank **100** at a location offshore, the tank **100** may be filled with a fluid lighter than seawater, such as light oil, in protective water and towed to a desired location. Seawater may then be pumped into the tank **100** while displacing the light oil to sink the tank **100** to the seabed **114**. The displaced light oil may be recovered and stored in an accompanying tank. For example, once at the desired surface location, seawater may be pumped into the inlet **122** of the tank **100** until the weight of the seawater plus the weight of the tank **100** is sufficient to overcome the buoyancy force on the tank **100** which initially is full of light oil. Once the buoyancy of the tank **100** is properly adjusted with light oil and seawater, tank **100** is lowered to the seabed. Once the tank **100** is in place on the seabed **114**, the piles **102** around the tank **100** are installed and the offload line **103**, the inlet lines (at **122**), and the remaining system components are connected to the tank **100**.

[0050] Embodiments of a storage and offtake system may be used in conjunction with a subsea processing and/or gathering system as illustrated in Figures 7 and 8. For example, the subsea processing system may comprise a subsea oil and gas separator **136** for degassing liquid hydrocarbons produced from the subsea wells **132** (in Figure 7). An example of a subsea processing system is described in U.S. Patent Application No. __/______ filed on _______________, and entitled "Passive Low Pressure Flash Gas Compression System". As shown in Figure 8, when an embodiment of the invention is used with a subsea processing system, gas **134** separated from the liquid hydrocarbons may be routed to a gas handling system and the liquid hydrocarbons (oil) **121**, exiting the separator **136** at a lower

pressure can then be pumped via oil transfer pumps **135** into the inlet **122** of the tank **100**.

[0051] A seabed storage and offtake system in accordance with the invention may also be used in conjunction with an offshore production platform as a cost-effective option for providing storage or additional storage for processed hydrocarbons. For example, Figure 9 shows one embodiment of a seabed storage system used in conjunction with a conventional tension leg platform (TLP) **140**. The TLP may include storage facilities at **141** for storing a limited amount of processed hydrocarbons. In this example, hydrocarbons from the TLP **140** are conveyed to the seabed storage tank **100** through a supply riser **142** which extends from the platform **140** to the tank **100**. As discussed above, the pressure of the hydrocarbons entering the seabed storage tank **100** must be adequate to overcome the hydrostatic pressure at the external end **124** of the fluid channel **127**. However, with the help of the hydrocarbon column in the supply riser **142** from the platform to the tank **100**, the pumping energy required at the platform to transfer oil to the seabed storage tank **100** is significantly less than that for subsea processing.

[0052] An example of a seabed storage system used in conjunction with a SPAR platform **150** is shown in Figure 10. The platform **150** includes an integral storage vessel at **151** which may be used to store a limited amount of hydrocarbons. Similar to the previous example, stabilized oil is pumped from the SPAR platform **150** into a supply riser **152** feeding the seabed storage tank **100**. As discussed above, with the help of the oil column in the supply riser **152** leading to the inlet of the tank **100**, the pumping energy required at the platform **150** to transfer oil to the seabed storage tank **100** is significantly less than that for subsea processing.

[0053] One skilled in the art will appreciate that a subsea storage and offtake system may comprise a plurality of subsea tanks connected in series or parallel, as determined by the system designer without departing from the spirit of the invention. For example, one or more tanks may be connected to the tank **100** shown in Figures 3 and 4, such that when the water level in the tank **100** reaches a minimum level, hydrocarbons pumped into the tank will overflow into another tank. Alternatively, the group of smaller tanks may be connected in parallel, such that their capacities equal that of a larger tank and act like a single vessel with a common oil and water interface level. Methods for configuring a system to include a plurality of tanks connected in parallel or in series are known in the art.

[0054] Embodiments of the invention may include one or more of the following advantages. Embodiments of the invention may be used to provide "on-site" storage for offshore production so that large amounts of hydrocarbons can be continually produced during adverse weather conditions and avoid the need for a shuttle tanker to be stationed at the production site at all times. Embodiments of the invention may also be used in conjunction with a subsea processing system and/or a production platform. Embodiments of the invention may also be used to eliminate the need for costly deepwater pipelines to shore, and in some cases may be used to avoid expensive pipeline tariffs. Embodiments of the invention may also provide larger storage capacity for offshore production sites in deepwater that are less costly to operate and maintain than prior art storage systems primarily dependent upon shuttle tankers or submerged thick walled storage vessels. Embodiments of the invention may also be used to reduce the number of shuttle tankers required in a hydrocarbon transport fleet. These advantages are only examples of advantages that may be associated with one or more embodiments of the invention. Thus, the invention is not intended to be limited to any of the advantages noted above.

[0055] While the invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate that other embodiments can be devised which do not depart from the spirit of the invention as disclosed. Accordingly, the scope of the invention should be limited only by the attached claims.